SP-F9. Evaluation of the Feather River Hatchery Effects on Naturally Spawning Salmonids

February 28May 14, 2002

1.0 Introduction/Background

The California Department of Water Resources (DWR) constructed the Feather River Hatchery (FRH) to mitigate for the loss of salmonid spawning habitat lost when Oroville Dam was closed in 1967. Since the late 1960s, the FRH, operated by the California Department of Fish and Game (CDFG), has released millions of spring and fall chinook salmon fry, fingerlings, smolts and yearlings, and yearling steelhead to fulfill DWR's Oroville Federal Energy Regulatory Commission (FERC) license mitigation responsibility. The FRH releases provide significant contributions to ocean commercial and recreational fisheries (chinook salmon) and inland recreational fishery (chinook salmon and steelhead) (Dettman and Kelley 1987 and Cramer 1992). Spawning escapement data (Reynolds et al. 1993) indicate that the FRH has apparently met its implicit mitigation responsibility in that runs of fall and spring chinook and steelhead to the Feather River have been numerically greater, on average, than runs seen in the years immediately before construction of Oroville Dam.

As defined in this study plan the Feather River Hatchery includes the fish diversion dam below Oroville Dam, the fish ladder, holding tanks, hatchery buildings and raceways. A separate fish rearing facility, the Salmon Stamp funded Thermalito complex, is also included in this evaluation because chinook salmon reared in this enhancement program are derived from gametes taken at the main hatchery and production is mixed with that from the main hatchery for release in San Pablo Bay. Hatchery activities included in this study plan include spawner selection, egg take and fertilization, rearing practices (including disease control) and release strategies, including release site.

Before going further in this study plan it may be helpful to define a few commonly used terms.

- **Chinook salmon** – all races of the species *Oncorhynchus tshawytscha.*
- **Steelhead** – all races of the species *Oncorhynchus mykiss*.
- **Spring chinook** – a race of chinook salmon that typically enters freshwater in the spring and holds in the rivers until spawning in the early fall. This race or run typically spawned in the higher elevations of the Sierra Nevada. In this report, the term spring chinook is used for those that enter the Feather River in May and June as bright fish and spawn in the September/early October period. There was a native spring run in the Feather River.
- **Fall chinook** – a race that enters the rivers in the early fall and typically spawn within a few days or weeks. In this report, the term fall chinook is used for those fish that enter the river beginning in August and spawn in the September through December period, with peak spawning generally in October through early November. There was a native fall run in the Feather River.

- **Late fall chinook** - a race similar to the fall run except it spawns somewhat later in the year. Late fall chinook are currently most common in the upper Sacramento River but hatchery reared late fall chinook do stray into the Feather River.
- **Winter chinook** – a race that enters freshwater in the late winter/early spring and spawns in the late spring through mid-summer. The winter run is now restricted to the Sacramento River between Keswick Dam and Red Bluff.
- **Naturally spawning salmonids** – refers to all anadromous salmonids that spawn in the streams. Naturally spawning salmonids differ from wild salmonids in that there may be a significant fraction of the spawning population of direct hatchery origin.
- **Phenotype** – characteristics of a run based on run timing, size, in-stream holding times, timing of outmigration, etc.
- **Genotype** – characteristics of a run based on genetic composition of individual members of the population.

As defined in this study plan the Feather River Hatchery includes the fish barrier dam below Oroville Dam, the fish ladder, holding tanks, hatchery buildings and raceways. A separate fish rearing facility, the Salmon Stamp funded Thermalito complex, is also included in this evaluation because chinook salmon reared in this enhancement program are derived from gametes taken at the main hatchery and production is mixed with that from the main hatchery for release into San Pablo Bay. Hatchery activities included in this study plan include spawner selection, egg take and fertilization, incubation, rearing practices (including disease control) and release strategies, including release site. This evaluation includes an analysis of planting chinook salmon in Oroville Reservoir as part of a FERC mandated program to support a reservoir coldwater fishery.

The FRH is one of five major Central Valley hatcheries producing and releasing fall chinook (FRH, Coleman National Fish Hatchery, Nimbus Fish Hatchery, Mokelumne Fish Hatchery, Merced River Fish Facility), one of three producing and releasing steelhead rainbow trout (CNFH, Nimbus and FRH) and the only hatchery producing and releasing spring chinook. An examination of the effects of FRH operations and facilities must consider any impacts in the context of the past and present practices of the entire Central Valley complex of hatcheries. Waples (1999), in a paper on myths about hatcheries, emphasized that examination of hatchery impacts should look at hatchery programs in the context of fish culture and fisheries management, not the hatcheries per se.

Although there may be late fall chinook in the Feather River (~~B.Cavallo, DWR,~~A. Kastner, DFG personal communication) this study focuses on fall and spring chinook and steelhead. In spite of this focus the plan will address any impacts of hatchery operation on late fall, and winter chinook, that may stray into the Feather River

The study plan will focus on several potential impacts of hatchery operation on naturally spawning salmonids. These potential impacts include (adapted from NRC, 1966):

- Effects on harvest – both commercial and recreational fisheries for chinook salmon and recreational for steelhead. A concern is that production from the FRH and other hatcheries has lead to the mixed stock fisheries that can overfish depleted natural stocks.
- Genetic effects – Hatchery operations can potentially cause problems with ~~interbreeding~~inbreeding and outbreeding depression and loss of genetic diversity within and among stocks.
- Domestication – Hatchery practices can lead to genetic adaptation to the hatchery, an adaptation that can reduce overall population fitness.

The plan will also identify the positive aspects of hatchery operation such as contributions to commercial and recreational harvest and resulting economic contributions to society.

~~The general approach to the study involves completing several tasks involving: 1) an examination of past and present hatchery practices and other Central Valley hatcheries; 2), documenting the results of genetic analyses of chinook salmon and steelhead from the FRH and other Central Valley streams and hatcheries; 3), compiling the results of extensive tagging studies to estimate the contribution of FRH fall chinook production to ocean and recreational fisheries, escapement and to straying, and, 4) for steelhead, evaluate in-stream rearing, and possible competition, between hatchery produced and naturally produced fish. In addition, the study will examine potential changes in hatchery practices, such as releasing production spring run juveniles directly in the Feather River. The information derived from these, and from other study elements in the FERC process will be organized into a final comprehensive evaluation of the benefits and concerns about hatchery operations.~~

~~Hatchery evaluations as part of the FERC process will be coordinated with take and other issues associated with hatchery operations as part of DWR and CDFG obligations pursuant to provisions of the federal Endangered Species Act.~~

~~The following paragraphs provide a brief background on the mitigation goals of the FRH and some of the complications expected to be addressed in the hatchery evaluation process.~~

The general approach to the study involves completing several tasks involving:

1) defining the goals of the Feather River Hatchery;
2) an examination of past and present hatchery practices in the FRHand other Central Valley hatcheries;
3) documenting the results of genetic analyses of chinook salmon and steelhead from the FRH and other Central Valley streams and hatcheries;
4) analyzing the results of extensive tagging studies to estimate the contribution of FRH fall chinook production to ocean and recreational fisheries, escapement and to straying, and,
5) using information from other study elements examine the impacts of the hatchery on in-river water quality and disease transmission
6) for steelhead, evaluate in-stream rearing, and possible competition, between hatchery produced and naturally produced fish. In addition, the study will examine potential changes in hatchery practices, such as releasing production spring run juveniles directly in the Feather River. The information derived from these, and from other study elements in the FERC

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The following provides a brief background on the mitigation goals of the FRH and some of the complications expected to be addressed in the hatchery evaluation process.

The actual mitigation goals for the FRH are defined in terms of the numbers of eggs taken each year for rearing and the numbers of fish to be released as smolts or yearlings. CDFG (1999) has the following goals by race or species:

For Mitigation

Race or species	number of eggs to be taken	number and stage at release
Spring chinook	up to 7,000,000	5,000,000 smolts
Fall chinook	up to 12,000,000	6,000,000 smolts
Steelhead	up to 1,000,000	400,000 yearlings

For Ocean Enhancement – Salmon Stamp facilities at Oroville

Fall chinook	from egg take above	2,000,000 smolts

For Ocean Enhancement – Salmon Stamp facilities on the Mokelumne River

Fall chinook	up to 4,000,000 eggs from above fall chinook egg take

~~chinook~~Chinook salmon and steelhead eggs, adults, and juveniles from the FRH have been used at other hatcheries (Coleman National Fish Hatchery, Nimbus Hatchery on the American River and the Mokelumne River ~~Fish Facility~~Hatchery) when spawning escapement to the hatcheries, or other conditions, limited their production. In addition, for more than three decades researchers have used tagged and externally marked juveniles from the FRH to help address such important questions as (1) the rate at which juvenile salmon enter water diversions; (2) the importance of the Yolo Bypass to salmon production and; (3) the survival of juvenile chinook salmon through the Sacramento-San Joaquin Delta. These uses of eggs and juveniles complicate the hatchery evaluation by adding additional release points (with increased straying potential) for FRH produced fish.

~~Evaluation of the FRH as a DWR mitigation facility is also complicated somewhat by some non-mitigation aspects of the take and rearing of eggs from Feather River chinook salmon spawners. With support from California's Salmon Stamp Program, chinook salmon embryos from the FRH are used at the Thermalito Annex to rear and release juveniles beyond DWR's mitigation responsibilities (so called "enhancement production"). Eyed eggs from the FRH have been taken to CDFG's Mokelumne Fish hatchery for rearing in a similar Salmon Stamp supported chancement program. (In recent years escapement to the Mokelumne River has been adequate to satisfy mitigation and enhancement needs and there have been no egg transfers from the FRH.) Juvenile chinook salmon from the Feather River have also been used to stock inland reservoirs~~

~~(including Lake Orvoville and Lake Almanor above the hatchery) to provide cold-water sports fishing opportunities.~~

~~For purposes of the FERC process, the hatchery evaluation is limited to the mitigation aspects of the FRH. In reality, the evaluation must include all aspects of the hatchery operation and the mitigation portions subsequently sorted out. For example, mitigation and enhancement juveniles are routinely moved between the FRH to the Thermalito facilities for disease control and other purposes and the enhancement and mitigation production are mixed for transport to San Pablo Bay. Some juvenile chinook salmon planted in Oroville Reservoir may leave the reservoir during flood periods, move to the ocean and possibly return to spawn.~~

~~A final complication in analyzing the impacts of the hatchery involves changing hatchery practices over the past three plus decades. For example into the nineties, planting surplus fry in many Central Valley streams was a common hatchery practice. The 1999 hatchery operations plan (CDFG 1999) stipulates that this practice will no longer occur. At various times FRH chinook salmon have been planted in the Feather River as fry, fingerlings, smolts and yearlings. Since the mid 80s most of the production has been planted in San Pablo Bay. Also the length of time it takes to plant production chinook has changed from April through September to April through July – mainly due to the use of larger capacity transport vehicles. There are some indications that changes in release timing may have changed the straying rates (S Cramer, personal communication).~~

~~The early 1960s, when CDFG and DWR agreed to construct and operate the FRH, was a period when hatcheries were deemed appropriate mitigation for habitat loss. In recent years salmon biologists have come to recognize that hatcheries can affect natural salmonid runs (for example, Reisenbichler 1997), especially when operated without taking into account potential effects of hatchery releases on wild fish. For example, successful efforts by FRH hatchery staff to reduce instream and Delta mortality by trucking production to San Pablo Bay has resulted in some adults returning to other streams (a behavior called straying). Straying into other streams, in particular to those streams containing threatened wild spring run, can result in interbreeding that may reduce the genetic fitness of wild spring run. Effects on spring run, which formerly spawned high in the watershed, may be compounded further by the presence of Oroville Dam, forcing spring run to spawn in the same area as fall run. When combined with hatchery practices that potentially result in interbreeding of spring and fall run straying may pose a hazard to the genetic fitness of wild spring run and naturally spawning fall run. Using microsatellite markers, Hedgecock et al. 2001 found only one genotype in naturally spawning and hatchery chinook in the Feather River and that genotype was distinct from spring chinook on Deer, Mill and Butte creeks – looking more like fall chinook. If spring and fall chinook were genetically distinct, one would expect at least two genotypes, and perhaps even distinct natural and hatchery genotypes.~~ Evaluation of the FRH as a DWR mitigation facility is also complicated somewhat by some non-mitigation aspects of the take and rearing of eggs from Feather River chinook salmon spawners. With support from California's Salmon Stamp Program, chinook salmon embryos from the FRH are used at the Thermalito Annex to rear and release juveniles beyond DWR's mitigation responsibilities (so-called "enhancement production"). Eyed eggs from the FRH have been taken to CDFG's Mokelumne Fish hatchery for rearing in a similar Salmon Stamp supported enhancement program. (In recent years escapement to the Mokelumne River has been adequate to satisfy mitigation and enhancement needs and there have been no egg transfers from the FRH.) Juvenile chinook salmon from the Feather River have also been used to stock inland

reservoirs (including Lake Orvoville and Lake Almanor above the hatchery) to provide cold-water sports fishing opportunities.

For purposes of the FERC process, the hatchery evaluation is limited to the mitigation aspects of the FRH, including the FERC required planting of juvenile chinook salmon in Oroville Reservoir. In reality, the evaluation must include all aspects of the hatchery operation and the mitigation portions subsequently sorted out. For example, mitigation and enhancement juveniles are routinely moved between the FRH to the Thermalito facilities for disease control and other purposes and the enhancement and mitigation production are mixed for transport to San Pablo Bay. Some juvenile chinook salmon planted in Oroville Reservoir may have left the reservoir during flood periods, move to the ocean and possibly return to spawn.

A final complication in analyzing the impacts of the hatchery involves changing hatchery practices over the past three plus decades. For example into the nineties, planting surplus fry in many Central Valley streams was a common hatchery practice. The 1999 hatchery operations plan (CDFG 1999) stipulates that this practice will no longer occur. At various times FRH chinook salmon have been planted in the Feather River as fry, fingerlings, smolts and yearlings. Since the mid 80s most of the production has been planted in San Pablo Bay. Also the length of time it takes to plant production chinook has changed from April through September to April through July – mainly due to the use of larger capacity transport vehicles. There are some indications that changes in release timing may have changed the straying rates (S Cramer, personal communication).

In a recent ~~draft~~ report, the National Marine Fisheries Service (NMFS) and CDFG (NMFS and CDFG 2001) reviewed practices in Central Valley hatcheries operated by CDFG, including the FRH. The report identified three principal hazards of hatchery operations to listed winter and spring chinook and steelhead:

- Genetic hazards caused by reducing genetic diversity in depressed natural populations;
- Ecological hazards to natural populations caused by straying, including competition for spawning sites and disease transmission; and
- Management hazards caused by the inability to differentiate hatchery from wild stocks. (This inability may be masking declining productivity of natural populations.)

The report further cautioned that managers should be concerned about management and genetic hazards because they have high risks of occurrence. The hazards are particularly troublesome because they include the risk of extirpation of natural stocks. Several times in the main report and in an appendix (Appendix 1 "Off-site Release and Straying Subcommittee Report") the authors referred to straying as a "significant problem" and mentioned the present practice of releasing production in San Pablo Bay as a particular concern. The report included a recommendation to tag (and fin clip) and release all FRH spring production in the Feather River and consider the same release strategy for fall run production.

NMFS and CDFG recommended that all Central Valley hatcheries prepare Hatchery and Genetics Management Plans (HGMPs) to minimize the risks to threatened and endangered salmonids. NMFS (1999) developed a detailed format for the HGMP, intended to provide a single comprehensive source of hatchery information for planning and to satisfy permitting requirements under the federal Endangered Species Act (ESA). In a recent evaluation of the Coleman National Fish Hatchery (CNFH) and the Livingston Stone National Fish Hatchery (LSNFH), the U.S. Fish and Wildlife Service (USFWS) used the HGMP template for their biological assessment (USFWS 2001).

This NMFS/DFG report will be particularly important in the analysis of hatchery impacts in that, in a parallel effort, an interagency team is continuing to review DFG's salmonid hatcheries. This study plan and resulting documents should be consistent with DFG/NMFS efforts to address the same issues. It is likely that much of the information developed in this study will be incorporated into a HGMP.

Steelhead present somewhat of a special case with respect to the effects of hatchery operations on naturally spawning salmonids. This special case is because:

- Relative to chinook salmon, the FRH produces few juvenile steelhead.
- All juvenile steelhead ~~are~~production is released as yearlings in the Feather River.
- For the past few years all juvenile steelhead produced in Central Valley hatcheries must have external marks (adipose fin clips) to distinguish from wild fish. In addition FRH production is coded wire tagged.
- Juvenile steelhead may spend one or two years in freshwater before migrating to the ocean, and in some cases may not migrate at all. Outmigrants are relatively large compared to emigrating chinook salmon – 150 - 200 mm total length for steelhead compared to 40 – 120 mm for fall and spring chinook salmon.
- In contrast to chinook salmon some steelhead survive spawning and may return to the ocean, spawning again in subsequent years. (All steelhead spawned in the FRH are returned to the Feather River after spawning.)
- There is no commercial fishery for steelhead and the freshwater anglers are only allowed to keep hatchery (adipose clipped) fish. In addition, it appears that significant numbers of immature fish ("half pounders", ie immature steelhead that are 12-15 inches long) are taken in freshwater – many in the Feather River.

~~As summarized by McEwan (2001) the complex life history (including sampling difficulty) and the lack of commercial importance have resulted in less relatively little information about this Central Valley steelhead. The documentation leading to listing the Central Valley steelhead Evolutionary Significant Unit (NMFS 1996 and 1997, and Busby and others 1996) resulted in the compilation of much of the available information on west coast steelhead – compilations that will form the basis of this evaluation. For example, Busby and others used allozyme analyses to demonstrate that the genetic structure of steelhead from the Coleman National Fish Hatchery, the FRH and wild fish from Mill and Deer creeks and the Stanislaus River was similar and did not resemble the genetic structure of coastal populations. On the other hand, the genetic structure of steelhead from the Nimbus Hatchery and the American River resembled that of their founding stock from the Eel River.~~

~~2.0 Study Objectives~~

~~The objectives of this study plan are to:~~

- ~~determine the ongoing and future impact of the FRH's Oroville mitigation activities; and~~
- ~~develop information to be used in identifying and assessing the feasibility of potential protection, mitigation and enhancement measures.~~

~~To achieve these objectives ,~~As summarized by McEwan (2001) the ~~plan will:~~

- ~~Determine if operations at the FRH impact the genetic composition of spring~~complex life history (including sampling difficulty) and ~~fall chinook and steelhead runs~~the lack of commercial importance have resulted in ~~the Feather River.~~

~~Determine if operations of the FRH impact the genetic composition of spring and fall chinook and steelhead runs to other~~ comparatively little information about Central Valley ~~streams;~~steelhead. The documentation leading to listing the Central Valley steelhead Evolutionary Significant Unit (NMFS 1996 and 1997, and Busby and others 1996) resulted in the compilation of much of the available information on west coast steelhead – compilations that will be an important information source for the hatchery evaluation. For example, Busby and others used allozyme analyses to demonstrate that the genetic structure of steelhead from the Coleman National Fish Hatchery, the FRH and wild fish from Mill and Deer creeks and the Stanislaus River was similar and did not resemble the genetic structure of coastal populations. On the other hand, the genetic structure of steelhead from the Nimbus Hatchery and the American River resembled that of their founding stock from the Eel River.

- ~~Estimate the contribution of Feather River chinook salmon production to ocean and inland fisheries and to escapement to the Feather River and other Central Valley streams;~~
- ~~Evaluate the effects of FRH steelhead plants in the Feather River on naturally spawning steelhead in the Feather River.~~
- ~~Determine how hatchery operations might be modified in light of findings presented in this and interrelated studies.~~

2.0 Study Objectives

The objectives of this study are to:

- Confirm and clearly define the goals and objectives of the mitigation aspects of the FRH;
- Characterize the non-genetic attributes of salmonid resources in the Feather River and other Central Valley, including run size, timing, outmigration (timing and numbers) and historical abundance and distribution.
- Characterize the Central Valley fish management context in which the FRH operates including other hatcheries, interbasin transfer of genetic material, escapement goals and commercial and recreational fisheries management.
- Provide a comprehensive description of the physical and operation characteristics of the FRH for the 1967-2002 period of operation.

- Characterize the genetic composition of chinook salmon and steelhead spawning in the Feather River and entering the FRH;
- Characterize the genetic composition of chinook salmon and steelhead spawning in other Central Valley streams;
- Estimate the hatchery contribution to Feather River in-river and hatchery populations of chinook salmon;
- Estimate the numbers (and rate) of FRH chinook salmon that stray to other Central Valley streams and hatcheries;
- Estimate the numbers of chinook salmon from other Central Valley hatcheries that stray into the Feather River;
- Estimate the contribution of the Feather River Hatchery production to commercial and recreational fisheries;
- Assess the ongoing and future impact of the FRH's Oroville mitigation activities on naturally spawning Central Valley salmonid populations;
- As part of the above objective, specifically assess the likelihood of disease transmission from hatchery releases to wild fish (fish releases below the hatchery) and hatchery fish (fish released in Oroville Reservoir) and the direct and indirect effects of hatchery operation on water temperatures in the Feather River.
- Construct conceptual models of the role, and impacts of, FRH operation on chinook salmon and steelhead in the Feather River and in other Central Valley streams;
- Assess the contribution of the FRH to public education and outreach
- Assess the economic and other contributions of the FRH to the California economy;
- Develop information to be used in identifying and assessing the feasibility of potential protection, mitigation and enhancement measures.
- To the extent possible identify the effects of possible changes of hatchery operation on Central Valley salmonid populations, the commercial and recreational fisheries, and marine mammals.

3.0 ~~3.0~~ Relationship to Relicensing/Need for Study

~~The FRH is an integral component of the Oroville complex, and its operation has the potential to adversely affect naturally spawning salmonid runs. As mentioned previously a 2001 draft report by CDFG and NMFS suggests that the FRH practice of planting hatchery production in San Pablo Bay (instead of in-river) may have caused increased straying. This increased straying may have impacted chinook salmon and steelhead runs in other streams, in particular those with wild spring run (for example Mill, Deer and Butte creeks). The report also suggested that hatchery practices have co-mingled spring and fall chinook in the hatchery and impacted the threatened spring run.~~

~~On the positive side, the FRH has released millions of juvenile salmon in the past 30 plus years and there are more steelhead, and chinook salmon returning to the Feather River each than prior to construction of the Oroville Dam.~~The FRH is an integral component of the Oroville complex, and its operation has the potential to adversely affect naturally spawning salmonid runs. As mentioned previously a 2001 draft report by CDFG and NMFS suggests that the FRH practice of planting hatchery production in San Pablo Bay (instead of in-river) may have caused increased straying. This increased survival and straying may have impacted chinook salmon and steelhead runs in other streams, in

particular those with wild spring run (for example Mill, Deer and Butte creeks). The report also suggested that hatchery practices have co-mingled spring and fall chinook in the hatchery and impacted the threatened spring run.

On the positive side, the FRH has released millions of juvenile salmon in the past 30 plus years and there are many steelhead, and chinook salmon returning to the Feather River each year. These fish appear to have made significant contributions to the ocean and inland commercial and recreational fisheries and escapement to the Feather River. After almost 30 years of operation, and with new thinking on the roles of hatcheries, it is time to evaluate the hatchery, its mitigation responsibility and operational practices.

Identification and quantification of project effects on fish and fish habitat has been recognized as an issue by relicensing stakeholders including stakeholders with mandatory conditioning authority and is a FERC requirement. Evaluation of project effects on wildlife resources is also required for CEQA/NEPA compliance.

Listings of the spring run as threatened pursuant to the federal and state endangered species acts and steelhead as threatened under the federal Endangered Species Act require that the State obtain take authorization in order to operate the hatchery. Although the fall run is not listed (but is a candidate species) under the federal ESA, there is considerable concern about the effects of hatcheries on naturally spawning fall chinook runs in the Feather River and other Central Valley streams. As mentioned previously, NMFS may require that hatcheries affecting listed species, such as the FRH, prepare ~~hatcheries~~ hatchery and genetic management plans. Information collected and reported in this evaluation can form the basis for such a plan for the FRH.

These and other issues about hatchery operation must be addressed in the FERC relicensing process and, in light of the results of this study and analyses, the new FERC license may stipulate changes in hatchery practices.

Section 4.51(f)(3) of 18 CFR requires reporting certain types of information in the FERC application for license of major hydropower projects, including a discussion of fish, wildlife and botanical resources in the vicinity of the project. The discussion needs to identify the potential impacts of the project on these environmental resources, including a description of any anticipated continuing impact for any on-going and future operation. This study fulfills these requirements by evaluating potential project effects on anadromous salmonids and their habitat in Feather River below the Fish Barrier Dam.

4.0 Study Area

This study plan is designed to evaluate the impact, if any of FRH released salmonids on natural spawning salmonids in the Feather River and other Central Valley streams. In addition this study will evaluate whether the FRH has satisfied DWR's mitigation requirements, ~~including supplementing~~ and supplemented chinook salmon harvest in the ocean commercial and recreational fisheries. The study area thus includes:

- the hatchery site (including the fish barrier dam and ladder)~~;~~
- Oroville Reservoir (due to planting chinook for recreational harvest)
- the Thermalito facilities
- the Feather River from the fish barrier dam to its confluence with the Sacramento River;
- the Sacramento River to its confluence with the San Joaquin River;
- the Sacramento-San Joaquin Delta;
- the San Francisco Bay;
- and the coastal ocean from southern California to British Columbia (the area where juvenile chinook salmon released from the FHR may be harvested in commercial and recreational fisheries).

Study plans approved by the Environmental Work Group define the limits of the study area. If initial study results indicate that the study area should be expanded or contracted, the Environmental Work Group will discuss the basis for change and revise the study area as appropriate.

5.0 General Approach

Evaluation of the FRH impacts will be based on review and synthesis of the vast amounts of information collected about the hatchery, the Feather River and other locations in the Central Valley and the Pacific Ocean. Of particular importance ~~is the review of~~ are: the recent biological assessment of the effects of the CNFH on salmonids (USFWS 2001), the NMFS/DFG review of California's salmonid hatcheries (NMFS/DFG 2001) and the NMFS guidelines for a Hatchery Genetics Management Plan (~~HGMP, see USFWS 2001 for components of HGMP.~~

~~In addition to compilation and analysis of existing data and literature, the hatchery evaluation will include additional field data collection and analysis. Much of this evaluation will be based on a hatchery marking study began in 1994. In each year of the study from 1 to 1.5 million production fish have been marked with adipose fin clips and magnetic coded wire tags implanted. Most of these tagged fish were released in San Pablo Bay but each year control groups, consisting of 200,000 tagged fingerlings and 100,000 tagged yearlings were released in the Feather River below the Thermalito outlet. The allocation of tags between putative hatchery spring and fall runs varied each year. Some of the tagged fish were subsequently recovered and the tags decoded in sampling at the Delta pumps, in midwater trawls at Sacramento and Chipps Island, in the ocean fisheries, in the inland fishery, during spawning ground surveys and at the FRH and other Central Valley hatcheries~~NMFS 1999).

~~As mentioned previously, all juvenile steelhead produced at the FRH are tagged and externally marked. Although all steelhead produced at other Central Valley hatcheries have the external marks, almost none of them are tagged. (The exception is that a few experimental fish from the Coleman National Fish Hatchery have been tagged. Jim Smith, personal communication.) The IEP has provided portable tag detectors to crews at the hatcheries and other field locations. If a marked fish has a tag, the fish is to be sacrificed and the tag decoded. This information can provide an idea of movement, including straying of Feather River steelhead. A caveat is that the relatively small number of releases (the production is 400,000 yearlings) and the difficulty in capturing steelhead may not produce sufficient tag returns to provide a statistically useful sample size.~~

Compilation and analysis of existing data will be accompanied by an extensive review of the literature about the impacts of salmonid and other hatcheries on natural spawning fish populations and communities as well as the use of hatcheries as a fish management tool. As stated by Waples (1999) " Hatcheries are intrinsically neither good nor bad – their value can only be defined in the defined context of clearly defined goals." The goal of this evaluation is to assess the hatchery in the context of specific hatchery and fish management goals. It is possible that some of the original hatchery goals may change in response to this evaluation.

~~In addition to tagging the production fish, through other funding a three-year study used coded wire tags to compare the survival of juvenile chinook salmon released in San Pablo Bay directly from transport trucks versus placed in floating net pens and towed towards mid Bay for release. Since net pen releases are now a standard operational practice, the comparison will provide an examination of the effects of this release strategy on ocean contribution and escapement.~~

In recognition of the uncertainty and complexity of the evaluation process, and the expectation that additional studies will be proposed during literature review and data interpretation, the study plan is divided into two phases. Phase 1 includes the literature review and analysis of data sets identified in specific phase I tasks. Phase 2 is open at this time. As Phase 1 progresses, tasks for Phase 2 will be identified and carried through the study plan approval process before being implemented. As a general guideline, all suggested Phase 2 studies must be completed by the end of 2003, including data collection, analysis and reporting.

The study will build on a longterm data collection and analysis effort organized by DWR to understand the hatchery and in-stream ecology of the Feather River system. Following are some of the key reports to be included in this analysis. (Complete citations are in the References section of this report.) Note that reports in draft stage are identified by italics. Authors and completion dates of the draft reports have not been determined but information in all these reports will be available for use in this analysis.

~~The fishery contribution rates and straying are being estimated by use of cohort analysis (Cramer 1992). Ocean and recovery data are now available through 2000 and inland recoveries through 1997. The cohort analysis will be updated as additional marked fish are recovered in the ocean and inland fisheries, on the spawning grounds and in the hatcheries. Preliminary analyses indicate that field sampling for marked fish on the spawning grounds is not adequate, thus additional recovery efforts will be designed, funded and conducted in the fall of 2002. Some additional tissues may be needed to verify the genetic identity of Central Valley salmonids, in particular fall run on the Mill and Deer creeks and adult chinook returning to the Feather River in the spring/early summer.~~

- Dettman and Kelly. 1987. The roles of the Feather and Nimbus salmon and steelhead hatcheries and natural reproduction in supporting fall chinook populations in the Sacramento River basin.
- Cramer. 1992. Contribution of Sacramento basin hatcheries to ocean catch and river escapement of fall chinook salmon.
- Brown and Greene. 1994. Evaluation of the Feather River Hatchery as mitigation for the construction of the State Water Project's Oroville Dam.

- Sommer, McEwan and Brown . 2001 Factors affecting chinook salmon spawning in the lower Feather River.
- Banks et al. 2000. Analysis of microsatellite DNA resolves genetic structure and diversity of chinook salmon (*Oncorhynchus tshwaytscha*) in California's Central Valley.
- Hedgecock et al. 2001. Application of population genetics to conservation of chinook salmon diversity in the Central Valley.
- McEwan. 1999. Feather River study – highlights of salmon emigration studies, 1996-1998.
- *DWR staff – Feather River spawning escapement – a history and critique.*
- *DWR staff – Emigration of juvenile chinook salmon and steelhead from the lower Feather River*
- *DWR staff - Species composition and the effects of environmental variables on fishes of the lower Feather River – 1997-2001.*
- *DWR staff - Redd dewatering and juvenile steelhead and chinook salmon stranding in the lower Feather River, 2000-2001.*
- *Cramer, In preparation. Estimation of total catch and escapement from fall chinook salmon produced at the Feather River Hatchery, 1967-1996.* Note that this analysis will be expanded to include spring run and subsequent years. The length of the period of record depends on the availability of tag recoveries from Central Valley streams and hatcheries. Ocean tag recovery, decoding and posting are complete through the 2001 fishing season.

Detailed Methodology and Analysis – Phase 1

Completing the following tasks will provide the information necessary to prepare an evaluation of the impacts of the Feather River Hatchery on naturally spawning Central Valley steelhead and chinook salmon.

Task 1. Define the goals and objectives of the mitigation aspects of the Feather River Hatchery. .

Completing this task is essential to the hatchery evaluation (Waples 1999) and will involve a review of the original FERC license, the subsequent modification to the FERC license requiring that DWR stock coldwater fishes in Oroville Reservoir and any DWR/DFG agreements about mitigation goals. As appropriate, this review will include agreements about the enhancement aspects of hatchery facilities and operations.

Task 2. Characterize the non-genetic aspects of the Feather River and other Central Valley salmonid populations and runs.

This evaluation is to examine the effects of the FRH hatchery on naturally spawning salmonids and this task is to describe the non-genetic aspects of those populations in detail. Recent population trends will be taken from the latest edition of the annual report by the Pacific Fisheries Management Council (for example, PFMC 2002). Historical information on distribution will be from Yoshiyama et al. 2001 and references contained therein. Some of the information to be compiled includes:

1. Population trends – for all major populations.
2. Flows and flow agreements – for the Feather River
3. Physical description of the river – for the Feather River
4. Spawning distribution and timing – for the Feather River and and other major streams
5. Outmigration timing –for the Feather River and other major streams.
6. In-river rearing, in particular for steelhead.

Much of this information will be developed as part of SP-F10 and will be extracted for use in SP-F9.

Task 3. Characterize the Central Valley fish management context in which the FRH operates, including other hatcheries, interbasin transfer of genetic material, escapement goals and commercial and recreational fisheries management.

Reference materials will be used to describe anadromous salmonid management in the Central Valley. Important sources will be USFWS (2001), NMFS/DFG (2001), PFMC (2002), Busby et al. (1996) DFG (1998) and DWR/USBR (2000) and annual reports from Central Valley hatcheries. This task will focus on spring and fall chinook and steelhead.

Task 4 – Describe FRH facilities and operations by compiling and summarizing all relevant information for the period 1967-2002.

This information shall include, but not limited to:

1. Water source
2. Facilities (broodstock collection, broodstock holding, incubation, rearing)
3. Founding stock – origin and identity
4. Broodstock selection
5. Mating protocols
6. Incubation and rearing
7. Release including numbers, sizes and locations

The list of information needs has been adapted from the HGMP guidelines (NMFS 1999). The information will be compiled from annual reports (for example Schlichting 1978) and internal files.

Task 5. Characterize the genetic composition of chinook salmon and steelhead spawning in the Feather River.

The procedures for Tasks 5 and 6 are essentially the same and are briefly described below. For more detailed information the reader should see Banks et al. (1999, 2000) and Hedgecock et al (2001).

For various reasons in the mid 1990s DWR became interested in the use of genetic markers to discriminate among the four Central Valley chinook runs. Through a rigorous RFQ process, DWR selected researchers at UC Davis' Bodega Marine Laboratory to conduct the research. The researchers proposed to use highly polymorphic microsatellite markers (a class of variable number tandem repeat loci) to determine if run discrimination was possible. The research involved several phases:

- Identify significant populations to be sampled, including all four runs, several streams and Central Valley hatchery stocks.
- Contract with the California Department of Fish and Game to collect and archive tissue samples from the selected populations. Collection protocols were specified and DWR provided freezers in which the archived samples were to be held. A complete record was maintained of the source and disposition of the archived samples.
- Subsamples of the archived samples were periodically delivered to the Bodega Marine for analysis.
- Laboratory scientists either purchased or developed their own microsatellite markers for characterizing the genetic structure of Central Valley salmonids. The scientists developed a software program (Banks and Eichert 1999 to help convert the raw data into run discrimination.

- The researchers at Bodega periodically discussed their findings with a panel of other geneticists including Robin Waples (NMFS), Don Campton (USFWS) and Phil Hedrick (University of Arizona).

- To ensure credibility of the results, the researchers published in mainline technical journals.

These procedures were modified slightly during the course of the study to address specific fall/spring chinook issues on the Feather River. Preliminary results indicated that the genetic makeup of putative spring chinook and fall chinook in the Feather River were identical – and more similar to the Central Valley fall chinook profile than spring chinook profiles from Deer, Mill and Butte Creeks. Field and hatchery personnel, as well as the fishing community had documented a chinook run that met traditional spring chinook characteristics – i.e., early arrival on the spawning grounds, holding for a few months before spawning in the early fall. The researchers addressed the apparent phenotypic/genotypic anomaly by: collecting samples from those fish exhibiting spring run characteristics and by developing an additional suite of markers that might allow differentiation. The results of these additional analyses should be available later this year in a published article.

The work sponsored by DWR will not be only genetic characterization work that has been or is being conducted on Central Valley chinook salmon. Bernie May and his colleagues have been working on a CALFED funded project (San Joaquin River Basin Genetic Baseline Study – a study that also analyses tissue samples from the Sacramento basin) with the results expected to be published in September 2002. The NMFS Santa Cruz laboratory is embarking on a Comprehensive Assessment of Genetic Population Structure and Genetic Diversity for Central Valley chinook salmon. Other researchers have used mitachondrial DNA (Nielsen et al.) and allozymes (Winans et al ____)to look at divergence among Central Valley chinook salmon. DWR will contract with a geneticist to prepare a report that describes the information that bears on the question of spring/fall genetic divergence in the Feather River.

The genetic composition of Central Valley steelhead has not been as well documented as that for chinook salmon. The most complete set of information is from NMFS (1996) and this will likely be the primary data source. The DFG is organizing a comprehensive Central Valley steelhead sampling/analysis genetic program and some results from this study may be available by the end of 2003.

We are looking into another aspect of the genetic composition of both chinook salmon and steelhead – a search for scales taken from fish during days when hatchery production was minimal, 50s and 60s. If a good set of scales can be found, we will have them analyzed and compare the results with present day genetic results.

Finally, in either Phase 1 or 2, if it appears that additional samples from salmonids could yield useful information, we will work with the regulatory agencies to get permission to collect tissues and with laboratories to get the samples analyzed.

Subtask 1. Work with geneticists at UCD, Oregon State University and NMFS to develop information about genetics of Feather River chinook.

Subtask 2. Document these findings in separate report, probably prepared by a geneticist.

Subtask 3. After the summary report is available, in the spring of 2003, convene a small workshop of technical experts to discuss the implications of the findings to the Feather River and other streams.

Task 6. Characterize the genetic composition of chinook salmon and steelhead from Central Valley streams other than the Feather River.

This task is essential to looking at the effects of the FRH on naturally spawning salmonids in other Central Valley streams. The approach and information base will be the same as described in Task 5.

Task 7. Estimate the FRH contribution to the in-river and hatchery spawning population of fall and spring chinook returning to the Feather River

This task will use analysis of tag return data to estimate the fraction of natural spawners that are of direct hatchery origin, as well as the fraction of the broodstock taken by the hatchery of direct hatchery origin. The field and laboratory program to develop this estimate began in 1995 and was an outgrowth of the 1992 analysis by Cramer that indicated conclusions regarding the fraction of hatchery fish returning to the Feather River were limited by the number of tags applied at the hatchery.

The following is a brief summary of the procedures that have been and will be used to estimate the fraction of FRH chinook returning to the Feather River and the hatchery. The tagging program involves both spring and fall chinook thus tagging can also help determine if the spring and fall populations meet one of the key attributes of a Evolutionary Significant Unit - that is "the population is substantially reproductively isolated from other conspecific population units" (Waples 1995). The tagging studies help in this assessment by providing information about the fidelity of run designation at the hatchery – that is, spring run return as spring run and fall as fall run.

Many of the elements in this task are the same as in Tasks 8, 9 and 10. Differences will be noted as appropriate. The general study plan is as follows.

- In the late summer of each year a meeting with the hatchery manager, IEP staff and the tagging contractor was held to allocate the available tagging capacity among production tagging, tagging fish destined for Oroville Reservoir and tags for research in the Delta or other locations in the Central Valley. The hatchery personnel wanted the total number of tags applied to not exceed about 2 million. This usually meant that about 1 million tags would be applied each year to spring or fall run production releases. Each year we decided on the tag allocation between spring and fall chinook runs.

- The tagging crews usually started in late February with the largest fish available. Because even the larger fish were relatively small, ½ coded wire tags (as compared to full size tags) were used early. The tagging crews normally worked two shifts and could tag and clip the adipose fin of up to 50,000 fish per day.

- Tagged production fish were mixed in with total production for trucking and release in San Pablo Bay.

- Each year 200,000 tagged fingerlings and 100,000 tagged smolts were released in the Feather River below the Thermalito outlet. The purpose of these releases was to:

    - Evaluate annual changes in the estimated survival to Chipps Island. The survival estimates were developed by the USFWS by expanding the numbers of tagged fish captured in 10, 10-minute daily midwater trawls. The expansion took into account the fraction of the time sampled and the fraction of the cross-section sampled by the trawls. See Brandes and McClain (2001) for a more complete description of the survival estimating procedures. Some of the tagged fish were subsequently captured in the ocean fishery and these returns provided an independent survival estimate. Releases of tagged fish were also made in the Sacramento River near Sacramento, thus allowing the ability to assess the relative survival from in-river release locations and Sacramento to Chipps Island and the ocean.

    - The subsequent capture of in-river releases also allows a comparison of straying between on-site and San Pablo Bay release locations.

    - DWR funds part of DFG's ocean sampling program to help ensure that tags applied at the hatchery were recovered in the ocean commercial and recreational fisheries. The goal of the program is to sample about 20% of the ocean catch and these data are used to estimate ocean harvest. When possible, heads from adipose clipped salmon were taken and shipped to DFG's Healdsburg laboratory where the tags were extracted and read. The tag information was posted on an electronic data base maintained by the Pacific States Marine Fisheries Commission.

    - Beginning around September 1 of each year, field crews on the Feather River begin annual surveys to estimate the numbers of spawners. These surveys run through December in most years. In addition to obtaining data for spawning estimates, the field crews collect the heads of adipose clipped fish and the heads (and accompanying data) are forwarded to the Healdsburg laboratory. DFG conducted the spawning ground surveys until the fall of 2000. In 2000 DWR took over the survey work to provide a better estimate of spawning escapement and to collect a higher fraction of the tags (B.Cavallo, DWR personal communication).

    - Also beginning around September 1 of each year, the hatchery begins collecting broodstock for spawning. The heads of adipose clipped fish are collected and shipped to Healdsburg for extraction and decoding.

Tagging and tag recovery allows one to estimate the fraction of spawners in the Feather River that were of hatchery origin. There are many ways to calculate the estimates but the Interagency Ecological Program Central Valley Salmonid Team used a technique called cohort analysis. The procedure involved in a cohort analysis is a relatively straightforward expanded accounting of the numbers of fish from each release group that was caught in the ocean fisheries, caught in the inland fisheries, escaped to spawn in the river or were taken into the hatchery. (See Cramer 1992 for a more complete description of the analytical techniques.)

The cohort analysis requires that we have good estimates of the numbers of fish at each stage as well as the sampling effort used to collect the heads for decoding. For example, in the ocean fisheries the assumption is that the samplers see 20% of the fish. The hatcheries also provide good estimates in that all fish entering the hatchery are sampled. Freshwater harvest and escapement suffer from two problems. First the estimates of harvest and escapement generally have significant but unquantified error bars. Second the sampling effort to recover tags may not be well defined. To overcome these problems, the analyst must often make assumptions about the stream sampling efforts.

Subtask 1. Collect all FRH tag release, tag recovery information, ocean population and harvest, freshwater harvest, escapement and numbers of adults entering FRH into a common electronic data base.

Subtask 2. Use the collected data to conduct a cohort analysis for fall chinook to estimate the fraction of spawners on the Feather River and adults entering the hatchery that are of direct FRH origin.

Subtask 3. Have the draft cohort analysis report reviewed by technical experts. The main function of the review is to assess the validity of some of the assumptions in the analysis.

Subtask 4. Expand the cohort analysis to include spring chinook.

Subtask 5 Use the database to evaluate time for smolts and fingerlings to travel to Chipps Island, the relative survival of the life stages to Chipps Island, the annual variation in survival from the Feather River to Chipps Island, any differences in survival to Chipps Island between the past few years and the 70s (have things gotten more fish friendly through the Delta) and return of the in-river planted fish to the Feather River.

Subtask 6 In the fall of 2002, increase sampling on the Feather River to ensure that an adequate, and known, percentage of the tagged fish are recovered on the spawning grounds.

Subtask 7 Review the report by Bailey and Munroe (2000) to determine if the information from their analyses (using a different technique) yielded similar results to the cohort analysis.

Subtask 8 In the spring of 2003 redo, with modifications as necessary, the cohort analysis with data from additional inland recoveries.

Subtask 9 Use the tag recovery data to estimate overall survival of hatchery releases. These estimated survival rates will be compared to literature values and other data as appropriate.

Task 8. Estimate the numbers and percentage of Feather River Hatchery chinook salmon that stray to other Central Valley streams.

Although the general assumption is that hatchery practices result in increased straying, information indicates that straying among natural and hatchery salmonid populations is variable and not well known (see for example, Quinn 1993).

This task uses the database described in Task 7 to examine the question of the amount of straying experienced by FRH production fish released mostly in San Pablo Bay. The major difference between data collection in tasks 7 and 8 is that tag collection on other streams is by non-DWR crews. Some information indicates that field crews may not be recovering tags in proportion to their occurrence in the spawning population. For example in 2000 on Battle Creek, the DFG field crews collected tags on about 2 percent of the spawners, about 6 percent of the spawners entering the hatchery had tags and and an informal survey of carcasses by USFWS staff found that about 7 percent of the carcasses had tags. Similar results were found in 2001. (K. Neimala, USFWS personal communication) On the Feather River the percentage of tags decreased markedly as the numbers of spawners increased. (B.Cavallo, DWR personal communication) These findings indicate that estimates of hatchery contribution to in-river spawning and straying will be biased low.

Subtask 1. Use the tag recovery data base to tabulate numbers of strays from FRH releases that were found on other streams and in other Central Valley hatcheries.

Subtask 2. Use cohort analysis to estimate the numbers and percentage of strays to Central Valley streams and hatcheries.

Subtask 3. Compare straying rates of chinook salmon released from the Coleman National Fish Hatchery (all fall chinook on-site releases) to off-site releases from the FRH.

Subtask 4 Investigate the use of a straying index as developed by the USFWS in their biological assessment of artificial propagation at the CNFH and LSNFH. (USFWS 2001).

Subtask 5. Survey literature to determine if straying rates noted in this study differ significantly from other results and if observed rates pose a serious problem for naturally spawning salmonids in other strerams.

Subtask 6 In the fall of 2000 arrange for special surveys of Mill, Deer and Butte creeks. Information from DFG indicates that tag recovery efforts on these streams are minimal – mainly due to sampling difficulty. The three streams have native spring runs and one concern is that spring chinook from the Feather River Hatchery may be straying to these streams.

Subtask 7 Continue to work with DFG and others to improve tag recovery efficiency, including documentation of sampling effort.

Task 9. Estimate the numbers of chinook salmon from other Central Valley hatcheries that stray into the Feather River and other Central Valley streams.

Most Central Valley salmon hatcheries tag a substantial number of their production releases – the exception being the Nimbus Hatchery. (And even at Nimbus as a result of a CALFED grant several hundred thousand smolts have been tagged and marked in 2001 and 2002. The goal of this task is to evaluate the overall level of straying within the Central Valley. It should be noted that tag recoveries to date indicate that there is no straying of Central Valley hatchery fish into the Klamath-Trinity system or vice versa. Tags from the Central Valley have been recovered in the ocean fisheries off Oregon, Washington and British Columbia but no stream tag recoveries have been reported. Completion of this task uses the same tag recovery database as in Tasks 7 and 8.

Subtask 1. From tag data base, compile list of tag releases from other Central Valley hatcheries and recovery of these tags in inland waters.

Subtask 2. Use cohort analysis to estimate the contribution rates of individual hatcheries to escapement in the Feather Rive and other Central Valley streams.

Subtask 3. Use the collected data to determine if there are release patterns (for example, size at release, release location) that seem to affect straying.

Task 10 Estimate the contribution of Feather River, and other Central Valley hatcheries, to the ocean and inland fisheries.

In the Pacific Northwest, fish from salmon hatcheries make up an estimated 70-80% of the ocean catch. Similar estimates from California are somewhat lower (Dettman and Kelley 1987 and Cramer 1992) but indicate that the hatchery contribution is significant. Hatchery contribution from the Central Valley is positive in that the catch of hatchery fish helps support the ocean troll and recreational fisheries off California and southern Oregon. The hatchery contribution can have negative impacts in that it may support a fishery that harvests more fish from naturally spawning (and even wild) stocks that is supportable in the long term. Hatchery fish in the ocean also are part of the ocean ecosystem, providing food for some components (for example, marine mammals) and being predators on other components.

Subtask 1. Use the tag recovery data base and other information to estimate the contribution of individual Central Valley salmon hatcheries to ocean harvest – both commercial and recreational.

Subtask 2. To the extent possible, use existing information from PFMC and other sources to determine trends in ocean harvest and fraction of harvest supported by Central Valley hatcheries.

Task 11. Assess the ongoing and future impacts of the FRH on naturally spawning salmonids in Central Valley streams.

This task will be the synthesis of much of the information in the previous tasks. (Note that disease transmission and effects of the hatchery on stream water temperature are identified separately in Task 12 below. This separation is mostly procedural – in the final report, the disease and temperature effects will be integrated into the overall evaluation.)

Literature review will be a key component of this assessment. Literally hundreds of reports and papers are available on the topic of hatchery impacts. The literature can provide examples of where impacts have occurred and been documented. The reviewer must then determine if the situation and findings are applicable to the Feather River situation.

Before going to the subtasks, the following is a list of potential hatchery impacts that will be used to guide the initial literature review. The list was developed by Eric Theiss of NMFS. Note that the list is preliminary and will be added to and modified as we go through the process.

1. effects on run timing
2. effects on morphology
3. outbreeding depression
4. reduced predator avoidance
5. disease transmission to wild fish
6. selection for non-territorial behavior in pre-smolts
7. selection for reduced activity in presmolts
8. early maturation in smolts
9. increased numbers of two-year olds (jacks) in the spawning population
10. unintentional mating of behaviorally/physically deficient fish – inbreeding depression
11. hybridization between runs
12. loss of ability/motivation to negotiate fast-flowing water
13. genetic transmission of hatchery-selected traits to wild fish

~~The conceptual foundation for the evaluation is found in the attached conceptual model. In summary, the model is as follows.~~

Subtask 1. Organize a technical review committee to assist in reviewing the products of this evaluation. This review committee could include members of the current technical input group augmented by one or two specialists. Much of the material to developed will be highly technical and not in the realm of technical expertise of most of the participants. A representative from the CNFH would be an important member of the technical review team.

- ~~The FRH rears steelhead and chinook salmon to mitigate for the loss of salmonid spawning and rearing habitat lost when Oroville Dam was constructed.~~
- ~~Releases of the juvenile steelhead and salmon in the river, in other streams and in San Pablo can result in straying to other streams and interbreeding of wild and hatchery fish.~~
- ~~This interbreeding can depress the fitness of wild chinook and steelhead.~~

- ~~Hatchery practices that select for certain traits (time of arrival at the hatchery, size, fecundity, etc.) as well as the general hatchery rearing conditions (feeding methods and diseases) may reduce the overall fitness of chinook salmon and steelhead and this reduced fitness may be transferred from generation to generation.~~
- ~~In the past few years a combination of a successful hatchery, an in-Bay release strategy, reduced ocean harvest, good ocean conditions, and spawners being drawn to the river channel immediately below the barrier dam has resulted in spawning runs that exceed the available spawning area. The large number of spawners competing for a relatively small area results in redd superimposition and may be affecting productivity of natural spawners.~~
- ~~Central Valley chinook salmon, including those in the Feather River, suffer from a variety of diseases. The occurrence and intensity of disease outbreaks can be intensified by intensive culture practices used in hatcheries and the diseases, in turn, may affect natural populations.~~
- ~~Drawing water from Oroville Reservoir to meet temperature requirements for hatchery operation may result in river temperatures that differ from historic conditions. The changed water temperature regime may affect naturally spawning and rearing salmonids.~~

Subtask 2. Conduct the literature review and document finding in a separate report. The initial focus of the literature review will be to address issues listed above, as well as other issues that arise during the review.

~~It must be kept in mind that this is an abbreviated conceptual model and that conceptual models are used to make hypotheses and assumptions explicit. The analyses being conducted are to help validate or refute the model with the goal of having a better model when the evaluation is complete.~~

Subtask 3. Use the results of the literature review and data from the previous tasks to assess the impacts of the hatchery, with particular emphasis on straying and its population effects.

~~If initial study results indicate that the methods and tasks should be modified, the Environmental Work Group will discuss the basis for change and revise the study plans as appropriate.~~

Subtask 4. Summarize the results of USFWS and NMFS studies that used FRH fish in various field studies. In many of these studies the investigators obtained physiological or morphological data on the test animals and in some studies evaluated the relative through-Delta survival of smolts from more than one hatchery.

~~Detailed Methodology and Analysis~~

~~Task 1 – Evaluate the Genetic Effects of FRH Practices on In-river Populations of Spring-run and Fall-run chinook Salmon and Steelhead~~

~~The gates to the fish ladder leads to FRH are generally open from about September 1 through the end of March. The early entries are ready for spawning in October. Through the mid-nineties fish entering the hatchery after October 1 were generally classified as fall-run. There is concern that this hatchery practice may have genetic effects on the in-river populations of chinook salmon and steelhead (see for example Hedgecock et al. 2001). In addition, spring and fall chinook now spawn in the same general time period in the area just downstream of the fish barrier dam. This co-mingling of spawners also increases the chances that spring and fall chinook are interbreeding. In 1999 DFG developed a hatchery operations plans (CDFG 1999) which modified and standardized processes to minimize chances of interbreeding spring and fall chinook. The new~~

procedures specify only those fish entering the hatchery between September 1 and September 15 will be considered spring run. chinook salmon entering the hatchery after September 15 will be considered fall run. In addition, no eggs will be taken for spring run production after October 7, even if the fish had entered the hatchery before September 15.

Subtask 5. Use the literature review and preliminary assessment to determine if additional field and/or laboratory work is needed in Phase 2. As part of this task, develop objectives and protocol for additional studies.

DWR began studies in 1994 and 1995 to help address genetic issues. The 1994 tagging studies, described previously, involved tagging both nominal spring and fall chinook in the hatchery. The time of tagging (and race as defined by hatchery staff) will be compared to the time the tagged adults return to the hatchery 2 or 3 years later. Previous studies (Brown and Greene 1994) have shown that fish called one race in the hatchery may return as another. (For example, the progeny of a spring run female spawned on October 1 may return and be spawned in early November and would be called a fall run.) The 1995 studies were part of a major effort by UC Davis scientists to determine the genetic diversity of Central Valley chinook salmon populations. Small tissue samples were collected from adult chinook salmon from major spawning streams and hatcheries and analyzed through use of a series of micro-satellite markers. (See Banks et al 2000 for a complete description of the methods used.)

Subtask 6. Arrange for periodic joint meetings with the DFG/NMFS hatchery task force to ensure that we are working towards mutual objectives.

Completing this task will requireTask 12, As part of Task 11 assess the following activities:

- Review and synthesize information relatedlikelihood of disease transmission from hatchery to the use of micro-satellite markers and allozymes naturally spawning fish (releases below hatchery) and to determine hatchery fish (releases above the hatchery) and the genetic composition of the three anadromous salmonid runsindirect effects of hatchery operation on water temperature in the Feather River; collect and analyze additional tissue as needed.
- Review and synthesize past, present and projected hatchery practices to determine the founding broodstock for each run and how broodstock selection procedures may be impacting genetic integrity of the three runs.
- Compile available information on production and outplanting of chinook salmon at the FRH.
- Compile and synthesize information about hatchery practices geared to increase production of FRH including predator control, food and feeding, movement of fish between Thermalito and the main hatchery and egg take and early incubation.
- Review and synthesize run timing and spawning location data to determine if the Feather River fall and spring runs are segregated in time or space.

Review coded wire tag data to determine the fidelity of putative FRH spring and fall run production when they return to the hatchery two to four years after release.

Task 2 – Evaluate the Effects of FRH Production on the Genetic Integrity of Spring run and Fall run chinook Salmon of Naturally Spawning chinook Runs in Other Streams

This task, based upon a literature review on genetic effects of salmon straying, available tag recovery data and modeling, attempts to address the question of what are the effects, if any, of FRH production on the genetic integrity of the spring and fall runs of Central Valley chinook salmon. Elements of this review will include:

This task will be covered under separate study plans (SP-F2 for disease and SP-W1 for temperature) and are listed here only for completeness. Although there is little evidence that hatchery diseases are spread to wild or naturally spawning fish (Waples 1999), the information on this topic is rather limited. At Oroville a more serious concern is that planting chinook salmon above the hatchery (as required by FERC) lead to increased problems with infectious hematopoietic necrosis virus (IHNV) in the FRH. Planting chinook in Oroville Reservoir has been stopped.

- ~~Reviewing literature on straying and genetic effects from other areas and in particular from Central Valley streams;~~
- ~~Review and synthesize physiological and morphometric information collected by NMFS and USFWS staff on FRH smolts with the goal of assessing any apparent reduction in fitness associated with hatchery rearing;~~
- ~~Examine genetic data developed in Task 1 to help determine if Feather River Hatchery produced fish are altering the genetic structure of runs to other Central Valley streams, and in particular to spring chinook in Mill, Deer and Butte creeks;~~
- ~~Use cohort analyses of tag recovery data to estimate the straying rates of production releases to other Central Valley streams (see Cramer (1992) for details;)~~
- ~~Use simple statistics to show the numbers of tagged FRH releases that have been recovered in other streams;~~
- ~~To correct a significant undersampling of tagged chinook and steelhead, conduct a "tag collection blitz" in the fall of 2002 and perhaps in 2003 to recover the maximum numbers of tags from Central Valley streams with particular attention to the Mill, Deer and Butte creeks and the mainstem Sacramento River between Red Bluff and Keswick Dam. This subtask would be contingent on securing funding from the Interagency Ecological Program, CALFED, and/or the Andromous Fish Restoration Program.~~

~~Task 3 – Evaluate the Contribution of FRH chinook Salmon Production to the Ocean and Inland Harvest and Escapement to the Feather River~~

~~The tagging studies and cohort analysis described earlier will also provide estimates of contribution of Feather River Hatchery produced fish to the fisheries and escapement. For the past several years, DWR through the Interagency Ecological Program has supplemented CDFG's ocean tag recovery efforts so that the agency samplers would be looking at about 20% of the fish being landed in the ocean fisheries off California. In a separate effort, the US Department of Interior's Comprehensive Analysis and Monitoring Program has funded DFG to estimate the numbers of chinook salmon harvested in the inland recreational fishery. The inland samplers have also been recovering some tags and the tags sent to CDFG's Healdberg laboratory for decoding.~~

Task 13 – Evaluate the effects of FRH steelhead planted in the Feather River on naturally spawning steelhead in the Feather River.

The significant differences in the biology and life history of chinook salmon and steelhead dictate that many aspects of the steelhead evaluation be handled in a separate task. Completing this task will require coordination between the in-river ecological project and integration of the results of these two components in the final synthesis report. Specific elements of this task include:

- Review applicable literature on the effects of steelhead conservation and production hatcheries.
- Summarize hatchery spawning and production for the period of record.
- Compile and assemble information collected in the Feather River pertaining to rearing and outmigration of juvenile steelhead. These data will include habitat use, food habits, catches of steelhead in rotary screw traps and other sampling methods.
- Examine tag return data to determine if they are adequate to describe the movement of FRH juvenile steelhead.
- Summarize information from DFG's recreational angler surveys to estimate harvest rate on hatchery steelhead.

~~This task will include:~~

Task 14. Construct conceptual models of the role, and impacts of the FRH operations on naturally spawning salmonids.

- ~~Use the cohort analysis to estimate contribution rates;~~
- ~~Review and synthesize information about ocean and inland harvest rates to determine if there are trends in these fisheries;~~
- ~~Estimate and contrast the contributions of FRH salmonid production and of naturally produced salmonids to harvest by the ocean and inland sport and commercial fisheries;~~
- ~~Review available data to determine changes in contribution rates due to changes in hatchery practices such as: release location (in-river, the Delta, San Pablo Bay); size at release (fingerling, smolt or subyearlings); and release method (directly from transport trucks, from net pens); and~~
- ~~As data permit, compare individual survival estimates for fish traveling from the Feather River to Chipps Island collected over the past two decades to determine if there are any trends. This analysis will be supplemented by in-river survival information from Battle Creek releases of tagged fish from the Coleman National Fish Hatchery. The objective is to determine if in-river has changed over the past two decades and if this change would affect hatchery production release strategies.~~

Conceptual models provide a useful and informative means of describing our understanding of the system. Including conceptual models as an explicit task will help make this understanding, and assumptions behind the understanding explicit. The following is a brief example of a conceptual model – a model that will be expanded as a result of this investigation.

~~Task 4 Evaluate the effects of FRH steelhead planted in the Feather River on naturally spawning steelhead in the Feather River.~~

~~The significant differences in the biology and life history of chinook salmon and steelhead dictate that many aspects of the steelhead evaluation be handled in a separate task. Completing this task will require coordination between the in-river ecological project and integration of the results of these two components in the final synthesis report. Specific elements of this task include:~~

- ~~Review applicable literature on the effects of steelhead conservation and production hatcheries.~~
- ~~Summarize hatchery spawning and production for the period of record.~~

- ~~Compile and assemble information collected in the Feather River pertaining to rearing and outmigration of juvenile steelhead. These data will include habitat use, food habits, catches of steelhead in rotary screw traps and other sampling methods.~~
- ~~Examine tag return data to determine if they are adequate to describe the movement of FRH juvenile steelhead.~~
- ~~Summarize information from DFG's recreational angler surveys to estimate harvest rate on hatchery steelhead.~~

~~Task 5 Evaluate the potential benefits and impacts of planting a significant portion, if not all of the spring run production in the Feather River.~~

~~In their 2001 draft report, NMFS and DFG proposed to consider planting all of the spring run production directly in the Feather River. If implemented, this proposal could affect the stream's ability to support naturally reproducing salmonid populations. A basic premise of Task 6 is that planting spring chinook in the Feather River should only occur after a thorough review of what we know and, if implemented, should employ an adaptive management approach – i.e. a graduated release schedule accompanied by extensive data collection and analysis. Elements of this task include:~~

- The FRH rears chinook salmon to mitigate for the loss of salmonid spawning and rearing habitat lost when Oroville Dam was constructed.
- Survival of juveniles planted in San Pablo Bay is higher than juveniles planted on site.
- Releases of production chinook salmon in San Pablo has resulted in straying to other streams and possible interbreeding of wild and hatchery fish.
- This interbreeding can depress the fitness of wild chinook.
- Straying rates can serve as surrogates for population impacts.
  Hatchery practices that select for certain traits (time of arrival at the hatchery, size, fecundity, etc.) as well as the general hatchery rearing conditions (feeding methods and diseases) may reduce the overall fitness of chinook salmon and this reduced fitness may be transferred from generation to generation.
- In the past few years a combination of a successful hatchery, an in-Bay release strategy, reduced ocean harvest, good ocean conditions, and spawners being drawn to the river channel immediately below the barrier dam has resulted in spawning runs that exceed the available spawning area. The large number of spawners competing for a relatively small area results in redd superimposition and may be affecting productivity of natural spawners.
- Central Valley chinook salmon, including those in the Feather River, suffer from a variety of diseases. The occurrence and intensity of disease outbreaks can be intensified by intensive culture practices used in hatcheries and the diseases, in turn, may affect natural populations.

Subtask 1. Develop a preliminary narrative conceptual model of chinook salmon life history in the Feather River as affected by operations of the FRH.

- ~~Through SP-F10 and other efforts assemble the available information on habitat use, condition factor, food use, food electivity and food composition in the Feather River from the barrier dam to the confluence with the Sacramento River.~~

- ~~Work with DFG and NMFS biologists to determine the numbers, size and locations of possible spring run releases into the Feather River. These discussions would be based in part on emigration patterns of natural spawning and estimated survival of hatchery spring chinook to Chipps Island and the ocean fishery.~~
- ~~As a special study in the springs of 2002 and 2003, increase releases of tagged hatchery spring chinook in the Feather River to help assure a statistically valid sampling size is available from recaptures at Chipps Island, the ocean fishery and on the spawning ground. In 2002 there will be three releases of 100,000 each. After reviewing these results DFG/NMFS/DWR would recommend the sample size and release timing for 2003.~~
- ~~Consider adding a rotary screw trap, or other juvenile salmonid sampling device, nearer to the mouth of the Feather River. This sampling could provide additional information regarding emigration of juveniles from the Feather River.~~

Subtask 2. Develop a preliminary narrative conceptual model of the steelhead life history in the Feather River as affected by operations of the FRH.

Task ~~6~~15. Assess the contribution of the FRH to public education and outreach.

The FRH provides a source of public education and outreach to the community. Although not technically part of an environmental evaluation, this component will summarize the number of field trips schools make to the hatchery each year as well as the annual salmon festival.

Task 16. Assess the economic contribution of the FRH to the California economy.

This economic analysis will focus on the contribution of the FRH to the ocean fishery.

Task 17. Develop information to be used in identifying and assessing the feasibility of potential new protection, mitigation and enhancement measures.

This task will look at FRH operation and may suggest measures to enhance operations (by limiting adverse impacts). Potential measures include:

- Changing the timing of spring run broodstock selection to the first few days in September, as originally practiced by hatchery managers.
- Tagging all spring run production.
- Releasing spring run production in the river.
- Find physical means of separating spring from fall spawners in the Feather River.

Subtask 1. Organize a meeting of interested biologists to discuss spring chinook on the Feather River and potential release and tagging strategies.

Subtask 2. In the spring of 2003 release three groups of tagged spring chinook smolts into the Feather River and follow their migration and survival to Chipps Island. This release would be the first part of an adaptive management experiment to assess the benefits and effects on in-river releases. Use of the present San Pablo Bay release site

may increase straying but does reduce other possible impacts of hatchery releases on naturally spawning salmonids – i.e., competition, predation and disease transmission.

Task 18– Prepare final report synthesizing the information from the above tasks in combination with information from other elements of the Oroville Project evaluation.

All the information related to this study plan will be compiled into a narrative report, with the report organized along the general format of a Hatchery Genetics Management Plan. Using this approach presents the information in a format readily used by DFG and NMFS in preparing the HGMP for the FRH. Specific FERC-related study elements expected to provide information for the final hatchery evaluation report are:

- SP-W1, Water quality, specifically with regard to the effects of hatchery produced fish on nutrients and dissolved oxygen in the river.
- SP-W6. Water quality, specifically the effects of the hatchery operation on stream temperature.
- SP-F10, In-river fish ecological assessments
- SP-F2, Disease studies

6.0 Results and Products/Deliverables

The information compiled in the above tasks will be assembled into a series of task specific reports. Where possible and informative, data will be organized and analyzed and presented in a series of figures and tables – the tables and figures forming the basis of many of the tasks reports. The ultimate deliverable will be the synthesis report that evaluates the overall effects of the hatchery on naturally spawning salmonids. The synthesis report will based on a combination of data directly related to the FRH and information gleaned from similar analyses of the effects of other hatcheries.

Review will be a key element of the reporting process. The authors of the task reports will submit drafts to appropriate technical and policy reviewers. Any comment will be addressed before the reports are made final.

7.0 Study Plan Coordination

Coordination With Other Resource Areas/Studies

Coordination with other FERC relicensing studies, including those addressing fish disease (SP-F2), salmoids in the Feather River (SP-F10), water quality (SP-W1 & SP-W6), and interbreeding of salmon stocks ~~(SP-E5)~~.

Evaluate the Likelihood Transmission of Disease from Hatchery to Wild Fish

- SP-F2 – Effects of Project Operations on Fish Diseases:

SP-F2 will provide information crucial to the evaluation of stocking practices and artificial production as it pertains to management of fish resources at Oroville facilities.

Many bacteria, virus and protozoa are known to cause various diseases to both wild and hatchery Pacific salmonids (e.g., the bacterium *Renibacterium salmoninarium* that cause bacterial kidney disease (BKD), the rhabdovirus causing infectious ~~haematopoietic~~ hematopoietic necrosis (IHN), the myxosporean parasite *Ceratomyxa shasta* that is lethal to most strains of rainbow trout). It is a current concern to catalogue and assess the incidence of diseases at FRH and evaluate the probability of spreading them to wild fish populations. Activities included in this task are detailed below.

- Review report by Scott Foote 2000 on similar concern about release of chinook from the Coleman National Fish Hatchery (CNFH);
- Review incidence of diseases at the FRH and CNFH to determine their similarities and if the conclusions from the Foote report can be applied to the Feather River; and
- Work with DWR's fish disease consultant to synthesize data.

Evaluate the Effect of Hatchery Produced Fish on Naturally Spawned Salmoids

- SP-F10 Evaluation of Project Effects on Anadromous Salmoids and their Habitat

Evaluate the Effects of the FRH on Water Quality in the Feather River

- SP-W1 Project Effects on Water Quality Designated Beneficial Uses for Surface Waters

Review the existing and newly acquired data to estimate the water quality effects of the decomposition of spawned salmon of hatchery origin that have returned to the Feather River.

Evaluate the Effect of Hatchery on Water Temperatures

- SP-W6 Project Effect on Water Temperatures

Issues, Concerns, Comments, Tracking and or Regulatory Compliance Requirements

This study would address the project-related effects of the Feather River Hatchery on naturally spawning salmonids. The following specific issues will be addressed: (The list identifies if the issues are directly or indirectly addressed in the study plan. Some of the more complex issues are in both categories. The underlined sentence or clause is the one that is best identified with each category);

Direct

Issue	Description
FE31	Several fish hatchery issues need resolution, such as the relationship between the hatchery and restoration of a natural ecosystem, straying and genetic impacts, harvest rates, and disease;

FE87	Introgression occurring between various runs of chinook salmon and between hatchery and wild salmon and steelhead. This includes direct, indirect and cumulative impacts from hatchery practices, project facilities and operations, lack of adequate spawning habitat and impassable migration barriers that exclude access to historic spawning habitats;
FE88	Impact of hatchery facilities and/or operations on anadromous salmonids. This includes the direct, indirect and cumulative impacts of hatchery product on anadromous salmonids and the direct, indirect and cumulative impacts of hatchery facilities and operations on salmonids and their habitats;
FE93	Introgression occurring between fall-run and spring-run chinook populations in the Feather River due to hatchery practices and impassable migration barriers;
FE99	The Feather River Hatchery was constructed to mitigate for losses of upstream habitat when the Oroville facilities were constructed. There is a body of evidence suggesting that improperly planned hatchery practices can adversely impact native and non-native species including anadromous species. The effects of hatchery practices on naturally reproducing/self-sustaining anadromous populations should be examined as part of the fishery investigations. These evaluations should examine alternative practices that would lead to increased naturally reproducing/self-sustaining anadromous populations. Improper hatchery practices can also lead to transmission of serious fish diseases, and impact overall susceptibility of naturally reproducing populations to diseases.
W13	Effects of existing and future hatchery operations on water quality and water temperatures in the Feather River and Afterbay;
WE33	Relationship between hatchery and water quality.

Indirect

Issue	Description
FE95	The lower Feather River provides habitat to support a variety of anadromous fish species including chinook salmon, steelhead, striped bass, American shad and sturgeon. Potential changes in license conditions could adversely impact habitat supporting these species. Habitat investigations should evaluate the existing quality and quantity of habitat and determine alternative improvements for the various life history needs of anadromous species including flow, water temperature, instream and riparian cover, substrate and spatial area;
FE87	Introgression occurring between various runs of chinook salmon and between hatchery and wild salmon and steelhead. This includes direct, indirect and cumulative impacts from hatchery practices, project facilities and operations, lack of adequate spawning habitat and impassable migration barriers that exclude access to historic spawning habitats;
FE96	The lower Feather River provides habitat to support a variety of resident native and resident introduced species including coldwater species such as rainbow, brook, and brown trout, and warm water species such as bass, catfish, bluegill, green sunfish, carp and others. Potential changes in license conditions could adversely impact habitat supporting these species or upset habitat conditions such that less desirable species are

	favored. Habitat investigations should evaluate the existing quality and quantity of habitat and determine alternative improvements for the various life history needs of these resident native and non-native species including flow, water temperature, instream and riparian cover, substrate and spatial area;

8.0 Study Schedule

The synthesis report will be completed by June 30, 2004. Individual tasks will be completed in time to meet the final report schedule but in most all cases, the task reports should be completed by March 1, 2003 to allow incorporation in the final report and sufficient opportunity for review. For some discrete components of the individual tasks, the deadlines are:

- Initial results of cohort analysis to estimate contribution and straying rates ~~– April~~ – June 1, 2002 ~~– part of Tasks 2, 3 and 6;~~
- ~~Results of mark recovery blitz – January 31, 2003 – part of Tasks 1, 2, 3 and 6.~~
- Results of increased sampling for tags on the Feather River and Mill, Deer and Butte creeks – March 1, 2003
- Second cohort analysis using additional tag recovery data – April 30, ~~3002 – part of Tasks 2, 3, and 6.~~2003.
- Literature reviews – December 31, ~~2003.~~2002. Part of all tasks.
- ~~Complete chinook salmon modeling development – March 1, 2003 – Task 5.~~
- ~~Analysis of effect of hatchery operation on stream temperature – August 31, 2003 – Task 4.~~

~~Complete additional analyses of genetic tissue – October 31, 2003 – part of Tasks 2 and 3.~~

- Complete final report – July 1, 2004

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